Zero is the only acceptable leakage rate for geologically stored CO2: an editorial comment

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Text published as an editorial comment in *Climatic Change (2009) 93:311–317*
The original publication doi:10.1007/s10584-009-9560-z is available at www.springerlink.com

Zero is the only acceptable leakage rate for geologically stored CO_2

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December 16th, 2008

Abstract

Leakage is one of the main concerns of all parties involved with the development of Carbon Capture and Storage. From an economic point of view, Van der Zwaan and Gerlagh (2009) suggest that CCS remains a valuable option even with CO_2 leakage rate as high as of a few % per year. But what is valuable is, ultimately, determined by social preferences and parameters that are beyond economic modeling. Examining the point of view of four stakeholder groups: industry, policy-makers, environmental NGOs and the general public, we conclude that there is a social agreement today: zero is the only acceptable carbon leakage rate.

Résumé

Le risque de fuite du carbone représente aujourd'hui l'une des préoccupations majeures des acteurs impliqués dans le développement de la technologie de Captage et Stockage du Carbone. Ce commentaire est une discussion autour des résultats de la recherche de Van der Zwaan et Gerlagh (2009) qui concluent à l'aide d'outils économiques que le CCS est une option envisageable même avec un taux de fuite de quelques % par an. Cependant, les préférences individuelles relèvent à notre avis davantage d'une convention sociale que d'hypothèses de modélisation. Dans une perspective plus ample, il apparaît ainsi essentiel d'examiner le CCS non seulement sous l'angle de l'efficacité économique, mais également sous celui du respect des conditions d'acceptabilité sociale, politique et technique du contrôle des risques liés au CCS. Aujourd'hui, ces conditions suggèrent que le seul niveau de fuite acceptable est le taux zéro. Pour le montrer, nous analysons le concept de fuite de carbone selon le point de vue de quatre parties prenantes: l'industrie, le régulateur, le public et des ONG environnementales. Le processus actuel de confrontation des positions ne pourrait conduire à un compromis sur une niveau de fuite socialement accepté non nul que dans les décennies à venir.

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Introduction

Is carbon capture and storage (CCS) a valuable option even if the CO_2 does not stay underground? For example, assuming that 2% of all CO_2 stored leaks back to the atmosphere every year, would it be an optimal use of the technology to store underground 50 GtC by 2100, then dealing with a CO_2 leakage of 0.9 GtC/year by storing even more, to keep the atmospheric concentration of CO_2 below 450 ppm ? Using an extension of DEMETER, a top-down integrated assessment model with detailed description of technical change extended to include CCS, van der Zwaan and Gerlagh (2009) suggest to answer positively: *We find CCS to remain a valuable option even with CO_2 leakage of a few % per year, well above the maximum seepage rates that we think are likely from a geo-scientific point of view.*

But the economic tools used to compare different leakage rates embody should reflect social preferences and we assess that today, zero is the only acceptable leakage rate for geologically stored CO2.

From an economic point of view the analysis of CCS with leakage is essentially a question of intertemporal valuation. With leakage, storing carbon in the ground is like taking a loan at the bank. One gets a benefit today. Then one pays back in a sequence of small installments. Payments sum up to more than the borrowed amount. In the case of CCS, this is because of the energy penalty: the energy needed to capture and store the CO_2 implies that to avoid emitting 1 ton of gas, one needs to store a bit more than 1 ton of gas.

In the standard analysis framework, the desirability of taking such a loan is then governed by the interplay of a few key parameters: the discount rate ***r***, the rate ***g*** at which the value of carbon grows over time, the leakage rate ***λ*** and the energy penalty ***1-c*** (one ton of CO_2 avoided is *1/c* ton stored). As discussed in Ha-Duong and Keith (2003), a larger discount rate makes storage more attractive in spite of leakage. A larger energy penalty or a faster growth of the carbon value makes leaky storage less attractive, or not attractive at all.

Van der Zwaan and Gerlagh (2009) use a discount rate ***r*** ≈ 5 % per year, mention that the energy penalty ***1 - c*** is about 0.3, and assume that the carbon value growth rate ***g*** is approximately 4 % per year up to 2060, and approximately zero after that date, because climate is then stabilized in terms of the atmospheric CO_2 content. With these orders of magnitude, a leakage rate **λ** at 2% per year does not preclude carbon capture and storage from being used massively along the optimal trajectory. By contrast, using the Markal model parametrized so that ***g*** does not go much lower than ***r*** even in the long run (Hotelling's rule), it is found that CCS disappears from the modelling optimum as soon as leakage rate is 1% per year or higher.

Thus, the key assumptions are the 5% discount rate and constant carbon value after 2060. One could wonder to which extend these parameters are theoretically consistent with a stabilization of the atmospheric CO_2 concentration at 450 ppmv, but there is already a large literature on discounting and intertemporal decision-making, assessed *e.g.* in Halsnæs *et al*. (2007). Still, alternative dynamics for the (***r***, ***g***) parameters may be also legitimate. The French Report on the social carbon value (CAS, 2008), for example, recommends a 4% discount rate and the application of Hotelling's rule, that is ***r*** = ***g***, after 2030. From 2010 to 2030, they suggest that the social carbon value should grow from 32 to 100 €/t CO_2, that is **g** > **r**. This reminds that ultimately, preferences with respect to the time and the environment are matters of social agreements rather than modeling assumptions. To clarify what the agreement could be, this commentary examines the social points of view on CCS and the acceptability of leakage, discussing successively businesses, administrations, environmental NGOs and the general public. While we focus on European actors, these findings could be generalized to other OECD countries where CCS is actively considered.

Leakage from the business operator's point of view

In Europe, the business point of view on CCS deployment is clearly articulated by a comprehensive stakeholders consortium, the European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP). This ZEP was founded in 2005 with the main purpose to facilitate the EU strategy of large-scale deployment of the CCS by 2020. In Europe there is a very significant policy interest for CCS, but numerous barriers remain to a widespread deployment of the technology. To overcome them, the ZEP estimates that ten to twelve demonstration projects in Europe are immediately necessary, and that the additional investment needed to build and run those are about 7 to 12 billions euros (Hill, 2008). Moreover, the uncertainty about the future carbon cost requires a policy framework making CCS economically sustainable. The development of a legal regulatory and liability regime to manage the leakage risk is also asked for urgently.

The question of leakage is also a great concern to the industry because the technology is still not widely accepted. An industrial accident on a demonstration project could have far-reaching social consequences, up to a ban on onshore storage. Engineers in charge of carbon storage projects argue that their only acceptable target is zero leakage. If there is evidence that the gas is moving above the geological structure where it is meant to stay, then the reservoir is not fit to be used anymore, the gas can and should be taken out and moved elsewhere. It is also argued that the risk of leakage tends to decrease after the end of the injection period, because the overpressure decreases as the gas moves around (pressure relaxation), in the long run the CO_2 can dissolve in surrounding water, and in the very long run it can be trapped very strongly by chemical reactions with the rocks.

Admittedly, to a large extend the word “leakage” as used by the industry has a different meaning from the word used to analyse the efficiency of CCS as a policy option. For companies, no leakage is a design constraint at the project scale, which is not the same as leakage at the global system scale. In most industries the design failure rate is zero, no probability of loss is acceptable. Airlines, for example, do not fly if there is any trouble with the craft. Yet at the global scale, there are accidents every year, and passengers take the risk.

While “no leakage” is the only acceptable specification for a storage site, the realized failure rate in the long run at the global scale is not only determined by geo-scientific expertise, but also and perhaps mostly by policy decisions. The safety criteria, monitoring standards and remediation practices will be set by regulations regarding the maintenance and abandonment of storage sites, which are essentially to be written yet.

Regulator's point of view

The regulatory framework on CCS is framed in broader policy goals of ambitious targets for CO_2 emissions, growth and energy supply security. With these objectives in mind, the European Council agreed in March 2007 to support a demonstration programme of up to twelve large-scale CCS projects in order to make the technology commercially viable by 2020. The direct goals are the acceleration of the CCS development in order to drive down costs through learning by doing and to build public confidence. At the same time, promoting CCS also aims to support European industries, create new jobs and promote technology leadership. Finally, European energy and emission targets would be more reachable in a carbon constraint environment with the deployment of CCS technology because today half of the EU electricity demand is met through fossil fuel-based power generation, which is expected to remain dominant in the coming decades. As the electricity generation infrastructure is aging and a large number of power plants will have to be retired, decisions for the construction of new capacities “capture-ready” need to be made in the near term (Tzimas *et al.*, 2008).

The existing regulatory framework already provides legal principles on the access to transport and storage sites, on monitoring, costs and particularly on the question of liability, but further specifications are needed, especially for the definition and assignment of risks. For instance, the capture is regulated under the Integrated Pollution Prevention and Control Directive, while transportation is regulated as natural gas transportation. Regarding leakage, the short term liability relates to process, trans-border operations, health and climate, which becomes complex as multiple operators are involved in the CCS chains. Long term liability relates mostly to seepage. The EU Directive on CCS states that the responsibility belongs to Member States for the geological storage after the shutdown, but the question remains on the liability inside each State during the CCS development and deployment.

The CCS Directive includes provisions to impose liability for the damage resulting from containment of carbon dioxide and applies the Environmental Liability Directive (2004/35/EC) to ensure the prevention and remedy of leakage by the operator. Liability for climate damage will be covered by the inclusion of storage in the revised EU ETS Directive and ETS allowances would have to be surrendered for leaked emissions. Each Member State will require operators to lodge financial security for their prospective liabilities that are to be defined at national level. Debates on liability provisions argue that governments may take on some of the burden like it is done for nuclear waste, *e.g.* in Germany and United States: nuclear plants take on private insurance and contribute to an industry trust fund too, as no insurer would cover for the full cost of a disaster.

The storage liability could be treated like hazardous waste or like natural gas storage. The final outcome will depend on the results of technological risk assessment research and on further actuarial and financial analysis of liability. So far very few real world observed data is available to base policy on, and failure events are hardly foreseeable with models. Optimal storage strategies will be revised later in light of new information. They should consider for example the risk that carbon value may increase faster than expected. Recognizing that the regulation process on leakage is iterative, we suggest that there may be a precautionary rationality at work behind the “no leakage allowed” approach today. It would be interesting to study that point analytically using dynamic programming.

Non Governmental Organisations: CCS as a bridging technology

Environmental NGOs have diverse views about CCS in the short term, even if they all agree that the large investments necessary to develop and disseminate the technology should not crowd out the efforts on energy conservation and renewables.

Greenpeace (2008) is perhaps the most representative of NGOs “against”. It argues that CCS is expensive in money and energy and there is the leakage risk. Other drawbacks cited include the lack of technological maturity, the absence of commercial viability and generally the uncertainties surrounding its effectiveness, regulation and environmental impacts. Carbon dioxide is seen as a waste, making CCS projects against the laws prohibiting burying waste.

The Friends of the Earth NGO is not against CCS demonstration projects as a transition technology to renewable energies, but adds that retrofitting coal power plant or building capture ready power stations could lead to a lock-in on coal-based generation technologies, that the capture process increases the demand for cooling water, and that there are environmental risks implied by leakage or sudden release of CO_2.

The Bellona Foundation is perhaps the environmental NGO most supportive of CCS, seeing it as an essential solution to curb greenhouse gas emissions quickly enough. They emphasize the necessity to decarbonize the increasing energy demand that will partly remain dependent on fossil fuels by 2050, and note that most of the developing countries, including China and India, have abundant coal resources. CCS becomes in this way an instrument to fight poverty as the technology presents the unique advantage of allowing for development without adding to climate change. In the Bellona Scenario to combat global warming, carbon capture and storage is implemented at all remaining fossil energy power plants by 2050, with the key message that: *carbon capture and storage (CCS) has the potential to significantly reduce CO2 emissions from fossil fuel power plants and large industrial sources. As such, CCS can be the bridge to the future renewable energy society*.

The Bellona Foundation acknowledges that geological storage projects will be selected and operated to avoid leakage, but they note that in rare cases, leakage may occur and remediation measures will be needed, either to stop the leak or to prevent human or ecosystem impact. Moreover, the availability of remediation options may provide an additional level of assurance to the public that geological storage can be safe and effective. Therefore appropriate remediation options must be identified in an event of a leakage scenario. The Foundation also recommends that evaluations on the risk of leakage through injection well, seal, and stress release events due to injection of CO2 and their probabilities on the release of CO2 should be a priority. Moreover, quantification of the short-term and long-term Health-Safety-Environmental (HSE) risks, in this case the likelihood of impacts on human and marine life should be assessed (Solomon, 2007).

While environmental NGOs differ on the short-term views, according to Anderson and Chiavara (2008), they could probably agree that in the long run only energy conservation and renewables are desirable, that no new coal plants without CCS should be built, and that renewable energy projects should receive a massive investment increase. All are seriously concerned about leakage, and consider CCS at best as a bridging technology, not as a long term solution. That view rejects the idea that the problem of leaky storage can be solved by re-capturing and storing more of the CO_2. It suggests that technology crowd out effects and scenarios driven by a constraint like "zero storage after 2100" would be interesting to explore.

Public opinion

In the literature, various observation tools from the field of sociology studies have been mobilized to understand better the public views about CCS. They include informed surveys, focus groups, citizens' panels, media analysis and field interviews around existing pilot projects. Studies, led in various developed countries, tend to show a common picture: the majority of people has low to zero familiarity with CCS (Ha-Duong *et al*., 2007). Both at the local and international levels CCS elicits moderate views, compared to views on nuclear and renewable energy which are more extreme.

In many studies, leakage appears as a key concern for citizens. For example, the survey of Itaoka *et al*. (2005) in Japan shows that the two most important factors influencing the public perception are leakage related risks and effectiveness in the long term. But the meaning of "leakage", in the context of public perception, can not be reduced to an annual rate. People's attitudes with respect to risks do not depend only on expected costs and benefits. Contrary to standard economic rationality, 0.001 probability of failure per year is not perceived subjectively as ten times less dangerous as a 0.01 rate.

Thus, disseminating technical and scientific information remains a key issue. Cultural values can change over time, and mass media powerfully influence people's perceptions about risks and uncertainty. They select information based on "news value", that is seek out the sensational and dramatic, which can lead to distortions in information communication. This could overestimate risks from new activities with lower fatality rates compared to more established risky industrial process. For example, much more airtime has been given to the Chernobyl nuclear disaster than to the fatalities recorded in the hydrocarbon and hydro-electricity industries. Given these distortions, accepting a small positive value is qualitatively different from declaring that only a zero leakage rate target is acceptable and remediation measures will be taken.

However, information plays only a small part in explaining beliefs and values. This is all the more so when scientists are uncertain and cannot realistically assess the optimal balance between the marginal risk of CCS and the marginal risk of climate change, not within one order of magnitude at least. Lay people intuitively know that they are not experts able to assess technical and legal standards, and tend to distrust scientific evaluations that oversimplify the reality. As a consequence, what the public perception is based on can not be an informed balance of risk versus risk, but on the trust in actors, the perceived justice and fairness of the decision process and other affects.

This is why communities tend to be interested in having a direct dialogue with independent specialist groups to have a say in risk control policies in a climate of confidence. When both scientific and public opinions are included in the decision process, the fairness of the procedure increases the acceptability of the CCS. In many societies today, it is not so much the hypothetical value of a technical long term leakage rate than dialogue as a condition of democracy that is critically important in shaping public perception. Transparency, information and confidence are the key elements.

Summary and conclusion

The economic tools used to compare different leakage rates embody intertemporal preference parameters. Their value should reflect social preferences. But these are not formed yet, the ongoing social process should lead to a socially accepted level for the leakage risk only in the next decade or so. To understand this process, it is necessary to consider beyond the purely economic efficiency all social and political views on CCS control, regulation and acceptance conditions.

Trade-offs can be made with other aspects on CCS and climate policies including technology, infrastructure, funding, the environment, health and safety, legal and regulatory issues.

Today the short-term and long-term leakage risk is one of the main preoccupations of all parties involved with the development of Carbon Capture and Storage. In the industry the only acceptable leakage rate to design storage is zero. Policy-makers have to set standards for long-term safety, but can not do so before having real-world data. Environmental NGOs see CCS only as a bridging technology, so more storage is not an acceptable answer to leakage, and the general public is also concerned about long term efficiency.

Considering that a few percent of leakage by year would be *relevant for specific site selection* amounts to ignore the technical and social aspects that would make the technology unacceptable due to human and ecosystem health concern. Moreover, the global average rate is an aggregate figure. Locally half of the sample will be over the median, possibly much higher in some sites. This is why, in our view, a one percent per year leak rate should in no case be considered *as target for probabilistic failure simulations or risk analyses for the assessment of individual storage locations*.

From economic perspective, when CCS with leakage is assimilated to a carbon loan, accepting leaking systems is like taking increasing amounts of financial debt. Recent macroeconomic developments remind that this is not sustainable.

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